3.5 PROCESS SAFETY ASSESSMENT

Process safety is the concern of employers and employees alike. Each company has the obligation to provide its employees with a safe and healthy work environment, while each employee is responsible for his/her own safe personal work habits. An effective process safety program identifies potential workplace hazards and, if possible, seeks to eliminate or at least reduce their potential for harm. In the MHC process of PWB manufacturing, these hazards may be either chemical hazards or process hazards. Chemicals used in the MHC process can be hazardous to worker health and therefore must be handled and stored properly, using appropriate personal protective equipment and safe operating practices. Automated equipment can be hazardous to employees if safe procedures for cleaning, maintaining, and operating are not established and regularly performed. These hazards can result in serious injury and health problems to employees, and potential damage to equipment.

The U.S. Department of Labor and the Occupational Safety and Health Administration (OSHA) have established safety standards and regulations to assist employers in creating a safe working environment and protect workers from potential workplace hazards. In addition, individual states may also have safety standards regulating chemical and physical workplace hazards for many industries. Federal safety standards and regulations affecting the PWB industry can be found in the Code of Federal Regulation (CFR) Title 29, Part 1910 and are available by contacting your local OSHA field office. State and local regulations are available from the appropriate state office. This section of the CTSA presents chemical and process safety concerns associated with the MHC baseline and substitutes, as well as OSHA requirements to mitigate these concerns.

3.5.1 Chemical Safety Concerns

As part of its mission, OSHA's Hazard Communication Standard (29 CFR 1910.1200) requires that chemical containers be labeled properly with chemical name and warning information [.1200(f)], that employees be trained in chemical handling and safety procedures [.1200(h)], and that a MSDS be created and made available to employees for every chemical or formulation used in the workplace [.1200(g)]. Each MSDS must be in English and include information regarding the specific chemical identity of the hazardous chemical(s) involved and the common names. In addition, information must be provided on the physical and chemical characteristics of the hazardous chemical; known acute and chronic health effects and related health information; exposure limits; whether the chemical is a carcinogen; emergency and first-aid procedures; and the identification of the organization preparing the data sheet. Copies of MSDSs for all of the chemicals used must be kept and made available to workers who may come into contact with the process chemicals during their regular work shift.

In order to evaluate the chemical safety concerns of the various MHC processes, MSDSs for 172 chemical products comprising eight MHC technology categories were collected and reviewed for potential hazards to worker safety. The results of that review are summarized and discussed in the categories below. General information on OSHA storage and handling requirements for chemicals in these hazard categories are located in the process safety section of this chapter. For a more detailed description of OSHA storage and handling requirements for

MHC chemical products in these categories contact your area OSHA field office or state technical assistance program for assistance.

Flammable, Combustible, and Explosive MHC Chemical Products

A breakdown of MHC chemical products that when in concentrated form are flammable, combustible, explosive, or pose a fire hazard is presented in Table 3.40. The following lists OSHA definitions for chemicals in these categories, and discusses the data presented in the table.

Table 3.40 Flammable, Combustible, Explosive, and Fire Hazard Possibilities for MHC Processes

MHC Process	Bath Type	Hazardous Property[a]			
		Flammable	**Combustible**	**Explosive**	**Fire Hazard**
Carbon	Cleaner	2 (2)			
	Conditioner	3 (3)			
	Other (Anti-Tarnish)	2 (2)			
Conductive Ink	Print Ink			5 (5)	
Conductive Polymer[b]	Polymer	1 (3)			
Electroless Copper	Accelerator	1 (5)			
	Anti-Tarnish	2 (4)			
	Cleaner/Conditioner	1 (8)		1 (8)	
	Electroless Copper	2 (25)	1 (25)		1 (25)
	Microetch	1 (9)			
Graphite	Microetch				1 (4)
Non-Formaldehyde Electroless Copper	Accelerator	1 (2)			
	Anti-Tarnish	1 (1)			
	Microetch	1 (4)			
Palladium	Accelerator			1 (10)	1 (10)
	Cleaner/Conditioner	1 (6)	1 (6)		
	Other (Anti-Tarnish)	1 (3)			

[a] Table entries are made in the following format **-** # of products meeting OSHA definition for the given hazardous property as reported in the products MSDSs (Total # of products in the process bath). A **blank** entry means that none of the products for the specific process bath meet the OSHA reporting criteria for the given property. Example: For the palladium process accelerator bath, 1 (10) means that one of the ten products in the bath were classified as explosive per OSHA criteria as reported on the products MSDSs.
[b] Hazardous properties based on German equivalent of MSDS, which may not have same reporting requirements of U.S. MSDS.

Flammable - A flammable chemical is defined by OSHA [29 CFR 1910.1200(c)] as one of the following:

- An aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback at any degree of valve opening.

- A gas that has: 1) at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less; or 2) when it, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12 percent by volume, regardless of the lower limit.
- A liquid that has a flashpoint below 100 °F (37.8 °C), except any mixture having components with flashpoints of 100 °F (37.8 °C) or higher, the total of which make up 99 percent or more of the total volume of the mixture.
- A solid, other than a blasting agent or explosive as defined in 29 CFR 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard.

Twenty chemical products are reported as flammable according to MSDS data. While all of the products have flashpoints near or below 100 °F, several of the products reported as flammable have flashpoints greater than 200 °F with one as high as 400 °F. Although several chemical products are flammable in their concentrated form, most chemical baths in the MHC process line contain non-flammable aqueous solutions.

Combustible Liquid - As defined by OSHA [29 CFR 1910.1200(c)], a liquid that is considered combustible has a flashpoint at or above 100 °F (37.8 °C), but below 200 °F (93.3 °C), except any mixture having components with flashpoints of 200 °F (93.3 °C), or higher, the total volume of which make up 99 percent or more of the total volume of the mixture. Two chemical products have been reported as combustible by their MSDSs, both with flashpoints above 155 °F.

Explosive - As defined by OSHA [29 CFR 1910.1200(c)], a chemical is considered explosive if it causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature. Seven chemical products are reported as explosive by their MSDSs.

Fire Hazard - A chemical product that is a potential fire hazard is required by OSHA to be reported on the product's MSDS. According to MSDS data, three chemical products are reported as potential fire hazards.

3.5.2 Corrosive, Oxidizer, and Reactive MHC Chemical Products

A breakdown of MHC chemical baths containing chemical products that are corrosive, oxidizers, or reactive in their concentrated form is presented in Table 3.41. The table also lists process baths that contain chemical products that may cause a sudden release of pressure when opened. The following lists OSHA definitions for chemicals in these categories and discusses the data presented in the table.

Table 3.41 Corrosive, Oxidizer, Reactive, Unstable, and Sudden Release of Pressure Possibilities for MHC Processes

MHC Process	Bath Type	Hazardous Property[a]				
		Corrosive	Oxidizer	Reactive	Unstable	Sudden Release of Pressure
Carbon	Cleaner	2 (2)				
	Conditioner	3 (3)				
	Microetch		2 (2)	2 (2)		
Conductive Polymer[b]	Catalyst	2 (3)				
	Conductive Polymer	2 (3)				
	Microetch	1 (1)				
Electroless Copper	Accelerator	1 (5)	1 (5)	3 (5)		
	Catalyst	5 (10)		2 (10)		
	Cleaner/Conditioner	5 (8)		2 (8)		
	Electroless Copper	11 (25)		5 (25)		
	Microetch	3 (9)	5 (9)	2 (9)	1 (9)	1 (9)
	Predip	4 (6)		2 (6)		
Graphite	Fixer	1 (1)				
	Graphite	1 (3)				
	Microetch	2 (4)	1 (4)		1 (4)	
Non-Formaldehyde Electroless Copper	Accelerator		1 (2)	1 (2)		
	Electroless Copper	2 (6)		1 (6)		
	Microetch	2 (4)	2 (4)	2 (4)		1 (4)
Palladium	Accelerator	4 (10)		1 (10)		
	Catalyst	4 (9)		1 (9)		
	Cleaner/Conditioner	1 (6)				
	Microetch			1 (5)	1 (5)	
	Other	2 (3)				
	Predip	1 (4)				

[a] Table entries are made in the following format - # of products meeting OSHA definition for the given hazardous property as reported in the product's MSDSs (Total # of products in the process bath). A **blank** entry means that none of the products for the specific process bath meet the OSHA reporting criteria for the given property. Example: For the graphite process microetch bath, 2 (4) means that two of the four products in the bath were classified as corrosive per OSHA criteria as reported by the products MSDSs.
[b] Hazardous properties based on German equivalent of MSDS, which may not have same reporting requirements of U.S. MSDS.

Corrosive - As defined by OSHA (29 CFR 1910.1200 [Appendix A]), a chemical is considered corrosive if it causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact, as determined by the test method described by the U.S. Department of Transportation 49 CFR Part 173 Appendix A. This term does not apply to chemical action on inanimate surfaces. A review of MSDS data found that 59 MHC chemical products are reported as corrosive in their concentrated form. Some MHC baths may also be corrosive, but MSDSs do not provide data for the process chemical baths once they are prepared.

Oxidizer - As defined by OSHA (29 CFR 1910.1200[c]), an oxidizer is a chemical other than a blasting agent or explosive as defined by OSHA [29 CFR 1910.109(a)], that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases. Twelve chemical products are reported as oxidizers according to MSDS data.

Reactive - A chemical is considered reactive if it is readily susceptible to change and the possible release of energy. EPA gives a more precise definition of reactivity for solid wastes. As defined by EPA (40 CFR 261.23), a solid waste is considered reactive if it exhibits any of the following properties: 1) is normally unstable and readily undergoes violent change without detonating; 2) reacts violently or forms potentially explosive mixtures with water; 3) when mixed with water, generates toxic gases, vapors, or fumes in a quantity that can present a danger to human health or the environment (for a cyanide or sulfide bearing waste, this includes exposure to a pH between 2 and 12.5); 4) is capable of detonation or explosive reaction if subjected to a strong initiated source or if heated under confinement; or 5) is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure. A review of MSDS data found that 25 chemical products from four different MHC processes are considered reactive.

Unstable - As defined by OSHA (29 CFR 1910.1200[c]), a chemical is unstable if in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shock, pressure, or temperature. Only three chemical products are reported as unstable according to MSDS data.

Sudden Release of Pressure - OSHA requires the reporting of chemical products that, while stored in a container subjected to sudden shock or high temperature, causes a pressure increase within the container that is released upon opening. MSDS data indicated only two chemical products that are potential sudden release of pressure hazards.

3.5.3 MHC Chemical Product Health Hazards

A breakdown of MHC process baths that contain chemical products that are sensitizers, acute or chronic health hazards, or irreversible eye damage hazards in their concentrated form is presented in Table 3.42. Also discussed in this section are MHC chemical products that are potential eye or dermal irritants and suspected carcinogens. The following presents OSHA definitions for chemicals in these categories and discusses the data in Table 3.42 where appropriate.

Table 3.42 Sensitizer, Acute and Chronic Health Hazards, and Irreversible Eye Damage Possibilities for MHC Processes

MHC Process	Bath Type	Hazardous Property[a]			
		Sensitizer	Acute Health Hazard	Chronic Health Hazard	Irreversible Eye Damage
Carbon	Carbon Black		3 (4)	3 (4)	4 (4)
	Cleaner		1 (2)	1 (2)	2 (2)
	Conditioner		3 (3)	3 (3)	2 (3)
	Microetch		2 (2)		2 (2)
	Other (Anti-Tarnish)		2 (2)	2 (2)	2 (2)
Conductive Ink	Print Ink				2 (5)
Conductive Polymer[b]	Catalyst				3 (3)
	Conductive Polymer				2 (3)
	Microetch				1 (1)
Electroless Copper	Accelerator		1 (5)		1 (5)
	Anti-Tarnish		2 (4)	2 (4)	2 (4)
	Catalyst		2 (10)	2 (10)	6 (10)
	Cleaner/Conditioner		1 (8)	1 (8)	3 (8)
	Electroless Copper		5 (25)	4 (25)	13 (25)
	Microetch		3 (9)	1 (9)	4 (9)
	Predip				5 (6)
Graphite	Cleaner/Conditioner		3 (4)	2 (4)	
	Fixer				1 (1)
	Graphite		2 (3)		1 (3)
	Microetch		3 (4)	2 (4)	2 (4)
Non-Formaldehyde Electroless Copper	Accelerator		1 (2)		
	Catalyst		2 (2)	2 (2)	
	Electroless Copper		3 (6)	2 (6)	4 (6)
	Microetch		3 (4)	1 (4)	3 (4)
Organic-Palladium[b]	Conductor				2 (2)
	Microetch				1 (1)
	Postdip				1 (1)
Tin-Palladium	Accelerator		1 (10)		9 (10)
	Catalyst		3 (9)	3 (9)	4 (9)
	Cleaner/Conditioner	2 (6)	1 (6)		2 (6)
	Microetch		2 (5)	2 (5)	3 (5)
	Other		2 (3)		3 (3)
	Acid Dip				1 (1)

[a] Table entries are made in the following format **-** # of products meeting OSHA definition for the given hazardous property as reported in the product's MSDSs (Total # of products in the process bath). A **blank** entry means that none of the products for the specific process bath meet the OSHA reporting criteria for the given property. Example: For the palladium process cleaner/conditioner bath, 2 (6) means that two of the six products in the bath were classified as sensitizers per OSHA criteria as reported by the products MSDSs.
[b] Hazardous properties based on German equivalent of MSDS, which may not have same reporting requirements of U.S. MSDS.

Sensitizer - A sensitizer is defined by OSHA [29 CFR 1910.1200 Appendix A (mandatory)] as a chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical. Only two chemical products were reported as sensitizers by MSDS data, both palladium MHC process chemicals.

Acute and Chronic Health Hazards - As defined by OSHA (29 CFR 1910.1200 Appendix A), a chemical is considered a health hazard if there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. Health hazards are classified using the criteria below:

- Acute health hazards are those whose effects occur rapidly as a result of short-term exposures, and are usually of short duration.
- Chronic health hazards are those whose effects occur as a result of long-term exposure, and are of long duration.

Chemicals that are considered a health hazard include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, nuerotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes.

A review of MSDS data found 51 chemical products reported as potentially posing acute health hazards, and 33 chemical products potentially posing chronic health hazards. OSHA does not require reporting of environmental hazards such as aquatic toxicity data, nor are toxicity data on MSDSs as comprehensive as the toxicity data collected for the CTSA. OSHA health hazard data are presented here for reference purposes only, and are not used in the risk characterization component of the CTSA.

Carcinogen - As defined by OSHA (29 CFR 1910.1200 Appendix A), a chemical is considered to be a carcinogen if: 1) it has been evaluated by the International Agency for Research on Cancer (IARC), and found to be a carcinogen or potential carcinogen; 2) it is listed as a carcinogen or potential carcinogen in the Annual Report on Carcinogens published by the National Toxicology Program (NTP); or 3) it is regulated by OSHA as a carcinogen. Formaldehyde, which is used as a reducing agent in the electroless copper process, is a suspected human carcinogen. A review of MSDS data found that six chemical products were reported as potential carcinogens. All of the products contain formaldehyde and are utilized in the electroless copper bath of the traditional electroless copper process.

Dermal or Eye Irritant - An irritant is defined by OSHA [29 CFR 1910.1200 Appendix A (mandatory)] as a chemical, which is not corrosive, but which causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is considered a dermal or eye irritant if it is so determined under the testing procedures detailed in 16 CFR 1500.41- 42. A review of MSDS data found that all but six of the 181 MHC chemical products reviewed are reported as either dermal or eye irritants.

Irreversible Eye Damage - Chemical products that, upon coming in contact with eye tissue, can cause irreversible damage to the eye are required by OSHA to be identified as such on the product's MSDS. A review of MSDS data found that 91 chemical products are reported as having the potential to cause irreversible eye damage.

3.5.4 Other Chemical Hazards

MHC chemical products that have the potential to form hazardous decomposition products are presented below. In addition, chemical product incompatibilities with other chemicals or materials are described, and other chemical hazard categories presented. The following lists OSHA definitions for chemicals in these categories and summarizes the MSDS data where appropriate.

Hazardous Decomposition - A chemical product, under specific conditions, may decompose to form chemicals that are considered hazardous. With few exceptions, the MSDS data for the chemical products in the MHC process indicate the possibility of decomposition to form a potentially hazardous chemical. Each chemical product should be examined to determine its decomposition products so that potentially dangerous reactions and exposures can be avoided. The following are examples of hazardous decomposition of chemical products that are employed in the MHC alternatives:

- When heated, a chemical product used to create an electroless copper bath can generate toxic formaldehyde vapors.
- If allowed to heat to dryness, a graphite bath process chemical could result in gas releases of ammonia, carbon monoxide, and carbon dioxide.
- Thermal decomposition under fire conditions of certain chemical bath constituents of a palladium cleaner/conditioner bath can result in releases of toxic oxide gases of nitrogen and carbon.

Incompatibilities - Chemical products are often incompatible with other chemicals or materials with which they may come into contact. A review of MSDS data found that all of the MHC processes have chemical products with incompatibilities that can pose a threat to worker safety if the proper care is not taken to prevent such occurrences. Incompatibilities reported range from specific chemicals or chemical products, such as acids or cyanides, to other materials, such as rubber or textiles, like wood and leather. Chemical incompatibilities that are common to products from all the MHC processes include acids, alkalis, oxidizers, metals, and reducing agents. Incompatibilities were also found to exist between chemical products used on the same process line. Individual chemical products for each process bath should be closely examined to determine specific incompatibilities and care should be taken to avoid contact with incompatible chemicals and chemical products, textiles, and storage containers.

The following are examples of chemical incompatibilities that exist for chemical products that are employed in the MHC alternatives:

- An electroless copper bath contains chemical products that, when contacted with hydrochloric acid which is present in other electroless copper process baths, will result in reaction forming bis-chloromethyl ether, an OSHA-regulated carcinogen.

- Violent reactions can result when a chemical product of the conductive polymer catalyst bath comes into contact with concentrated acids or reducing agents, both of which are used in PWB manufacturing processes.
- A microetch bath of a graphite process contains chemicals that will react to form hazardous gases when contacted with other chemical products containing cyanides, sulfides, or carbides.
- Hazardous polymerization of a particular conductive ink product can occur when the product is mixed with chemicals products containing amines, anhydrides, mercaptans, or imidazoles.

Other Chemical Hazard Categories - OSHA requires the reporting of several other hazard categories on the MSDSs for chemicals or chemical products that have not already been discussed above. These additional categories include chemical products that are:

- Water-reactive (react with water to release a gas that presents a health hazard).
- Pyrophoric (will ignite spontaneously in air at temperatures below 130 °F).
- Stored as a compressed gas.
- Classified as an organic peroxide.
- Chemicals that have the potential for hazardous polymerization.

A review of MSDS data indicated that none of the chemical products are reported as being water-reactive, pyrophoric, a compressed gas, an organic peroxide, or as having the potential for hazardous polymerization.

3.5.5 Process Safety Concerns

Exposure to chemicals is just one of the safety issues that PWB manufacturers may have to deal with during their daily activities. Preventing worker injuries should be a primary concern for employers and employees alike. Work-related injuries may result from faulty equipment, improper use of equipment, bypassing equipment safety features, failure to use personal protective equipment, and physical stresses that may appear gradually as a result of repetitive motions (i.e., ergonomic stresses). Any or all of these types of injuries may occur if proper safeguards or practices are not in place and adhered to. An effective worker safety program includes:

- An employee training program.
- Employee use of personal protective equipment.
- Proper chemical storage and handling.
- Safe equipment operating procedures.

The implementation of an effective worker safety program can have a substantial impact on business, not only in terms of direct worker safety, but also in reduced operating costs as a result of fewer days of absenteeism, reduced accidents and injuries, and lower insurance costs. Maintaining a safe and efficient workplace requires that both employers and employees recognize and understand the importance of worker safety and dedicate themselves to making it happen.

Employee Training

A critical element of workplace safety is a well-educated workforce. To help achieve this goal, the OSHA Hazard Communication Standard requires that all employees at PWB manufacturing facilities (regardless of the size of the facility) be trained in the use of hazardous chemicals to which they are exposed. A training program should be instituted for workers, especially those operating the MHC process, who may come into contact with, or be exposed to, potentially hazardous chemicals. Training may be conducted by either facility staff or outside parties who are familiar with the PWB manufacturing process and the pertinent safety concerns. The training should be held for each new employee, as well as periodic retraining sessions when necessary (e.g., when a new MHC process is instituted), or on a regular schedule. The training program should explain to the workers the types of chemicals with which they work and the precautions to be used when handling or storing them; when and how personal protection equipment should be worn; and how to operate and maintain equipment properly.

Storing and Using Chemicals Properly

Because the MHC process requires handling of a variety of chemicals, it is important that workers know and follow the correct procedures for the use and storage of the chemicals. Much of the use, disposal, and storage information about MHC process chemicals may be obtained from the MSDSs provided by the manufacturer or supplier of each chemical or formulation. Safe chemical storage and handling involves keeping chemicals in their proper place, protected from adverse environmental conditions, as well as from other chemicals with which they may react. Examples of supplier recommended storage procedures found on the MSDSs for MHC chemicals are listed below:

- Store chemical containers in a cool, dry place away from direct sunlight and other sources of heat.
- Chemical products should only be stored in their properly sealed original containers and labeled with the generic name of the chemical contents.
- Incompatible chemical products should never be stored together.
- Store flammable liquids separately in a segregated area away from potential ignition sources or in a flammable liquid storage cabinet.

Some products have special storage requirements and precautions listed on their MSDSs (e.g., relieving the internal pressure of the container periodically). Each chemical product should be stored in a manner consistent with the recommendation on the MSDS. In addition, chemical storage facilities must be designed to meet any local, state, and federal requirements that may apply.

Not only must chemicals be stored correctly, but they must also be handled and transported in a manner which protects worker safety. Examples of chemical handling recommendations from suppliers include:

- Wear appropriate protective equipment when handling chemicals.
- While transporting chemicals, do not use open containers.
- Use only spark-proof tools when handling flammable chemicals.

- Transfer chemicals using only approved manual or electrical pumps to prevent spills created from lifting and pouring.

Proper chemical handling procedures should be a part of the training program given to every worker. Workers should also be trained in chemical spill containment procedures and emergency medical treatment procedures in case of chemical exposure to a worker.

Use of Personal Protective Equipment

OSHA has developed several personal protective equipment standards that are applicable to the PWB manufacturing industry. These standards address general safety and certification requirements (29 CFR Part 1910.132), the use of eye and face protection (Part 1910.133), head protection (Part 1910.135), foot protection (Part 1910.136), and hand protection (Part 1910.138). The standards for eye, face, and hand protection are particularly important for the workers operating the MHC process where there is close contact with a variety of chemicals, of which nearly all irritate or otherwise harm the skin and eyes. In order to prevent or minimize exposure to such chemicals, workers should be trained in the proper use of personal safety equipment.

The recommended personal protective equipment for a worker handling chemicals is also indicated on the MSDS. For the majority of MHC chemicals, the appropriate protective equipment indicated by the MSDS includes:

- Goggles to prevent the splashing of chemical into the eyes.
- Chemical aprons or other impervious clothing to prevent splashing of chemicals on clothing.
- Gloves to prevent dermal exposure while operating the process.
- Boots to protect against chemical spills.

Other items less widely suggested include chemically resistant coveralls and hats. In addition to the personal protective equipment listed above, some MSDSs recommended that other safety equipment be readily available. This equipment includes first aid kits, oxygen supplies (SCBA), and fire extinguishers.

Other personal safety considerations are the responsibility of the worker. Workers should be discouraged from eating or keeping food near the MHC process. Because automated processes contain moving parts, workers should also be prohibited from wearing jewelry or loose clothing, such as ties, that may become caught in the machinery and cause injury to the worker or the machinery itself. In particular, the wearing of rings or necklaces may lead to injury. Workers with long hair that may also be caught in the machinery should be required to securely pull their hair back or wear a hair net.

Use of Equipment Safeguards

In addition to the use of proper personal protection equipment for all workers, OSHA has developed safety standards (29 CFR Part 1910.212) that apply to the actual equipment used in a PWB MHC process. Among the safeguards recommended by OSHA that may be used for conveyorized equipment are barrier guards, two-hand trip devices, and electrical safety devices.

Safeguards for the normal operation of conveyor equipment are included in the standards for mechanical power-transmission apparatus (29 CFR Part 1910.219) and include belts, gears, chains, sprockets, and shafts. PWB manufacturers should be familiar with the safety requirements included in these standards and should contact their local OSHA office or state technical assistance program for assistance in determining how to comply with them.

In addition to normal equipment operation standards, OSHA also has a lockout/tagout standard (29 CFR Part 1910.147). This standard is designed to prevent the accidental start-up of electric machinery during cleaning or maintenance operations that apply to the cleaning of conveyorized equipment as well as other operations. OSHA has granted an exemption for minor servicing of machinery provided the equipment has other appropriate safeguards, such as a stop/safe/ready button which overrides all other controls and is under the exclusive control of the worker performing the servicing. Such minor servicing of conveyorized equipment can include clearing fluid heads, removing jammed panels, lubricating, removing rollers, minor cleaning, adjusting operations, and adding chemicals. Rigid finger guards should also extend across the rolls, above and below the area to be cleaned. Proper training of workers is required under the standard whether lockout/tagout is employed or not. For further information on the applicability of the OSHA lockout/tagout standard to MHC process operations, contact the local OSHA field office.

Occupational Noise Exposure

OSHA has also developed standards (29 CFR Part 1910.95) that apply to occupational noise exposure. These standards require protection against the effects of noise exposure when the sound levels exceed certain levels specified in the standard. No data was collected on actual noise levels from MHC process lines, but one PWB manufacturer suggested protective measures may be needed to reduce noise levels from air knife ovens on carbon and graphite lines. This manufacturer installed baffles on his system to reduce noise levels (Kerr, 1997).

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